BENEFITS OF ANADROMOUS FISH TO THE ECOSYSTEM

RECIPIENT
algal and biofilm
Aquatic insects
Aquatic insects, cottids
Aquatic macroinvertebrates
Aquatic macroinvertebrates and gobeid fish
Atlantic salmon
Atlantic salmon and sea trout
Bald Eagle
bald eagle
bald eagles
Beaver dams
Beaver dams
Biofilm and benthic macroinvertebrates
Biofilm, aquatic macroinvertebrates and coho
Chum salmon

Coho and steelhead juveniles

Coho juveniles

Coho juveniles

Coho juveniles in beaver ponds

coho salmon

Cottids

Deer, coyote, bobcat, weasel
Ecosystem and resident salmonids

Ecosystem needs

Ecosystem retention

Ecosystem retention

Estuarial phytoplankton
Estuarine food web
freshwater and terrestrial ecosystems

gray wolf

Grizzly bear

Hyporheic zone

Hyporheic zone

Instream sediment

Killer whale
Kokanee

Lack of nutrients

Lake ecosystem

Lake macroinvertebrates

Lake primary productivity, phytoplankton succession, zooplankton biomass

Lizards

Marten

Mink

Nutrient delivery to upper watersheds

Old growth riparian conifers

Oysters/shellfish

Oysters/shellfish

Rainbow trout

resident rainbow, brown trout, mountain whitefish, chlorophyll-a, benthic invertebrates

Riparian conifers

Riparian insects

Riparian vegetation

Sitka and White spruce

Sitka spruce

Sockeye juveniles
Sockeye juveniles
Sockeye juveniles
Sockeye juveniles

Steam productivity

Steelhead

steelhead, coho

Steller sea lion

Steller sea lion

Stream nutrient loads
Stream productivity

Summary

Summary

Summary

Summary

Terrestrial invertebrates

Terrestrial vegetation

Using carcass benefits to set escapement goal

Using carcass benefits to set escapement goal

Varied Thrush, Song Sparrow, river otter, cougar, mink, raccoon, maggots, gulls, mice, beetles

Water shrew, Masked shrew, wandering shrew, deer mouse, Douglas squirrel, flying squirrel, coyote, raccoon, weasel, mink, skunk, bobcat, river otter, Red-tailed hawk, Bald Eagle, Dipper, Gray Jay, Stellers Jay, crow, raven, Winter Wren

White spruce

White-tailed deer

Zooplankton production in lakes

BENEFIT	SOURCE OF BENEFIT
Carcasses enhanced algal and biofilm growth but did not significantly influence wood decomposition	Salmon carcasses
Increased abundance	Nutrient application, controlled levels
Important in streams with concentrated spawning but may be minimal with sparse spawning levels. Benefit from primarily semelparous fish may depend on spawner density and availability of eggs.	blueback herring, rainbow smelt, Atlantic salmon
Carcasses were rapidly colonized and consumed, primarily by midges and a specific stonefly	pink salmon
Abundant colonization; at least some species more abundant on carcasses than on streambeds	Chum salmon
Even in iteroparous fish, dead spawners can contribute significant nutrients to a system with a naturally (geologically) low baseline of nutrients	Atlantic salmon
Adults impost more nutrients than is exported by smolts	Atlantic salmon and sea trout
Number wintering on Skagit River directly related to chum salmon estimated escapement	Chum salmon
Carrying capacity for overwintering directly correlated to chum and coho salmon escapement	Chum and coho salmon
Number of eagles positively correlated with spawner abundance	kokanee
Beaver dams increased rearing capacity of streams	
Presence in the Stillaguamish River system would increase coho smolt production potential from 0.965 (current) to 2.5 million.	
Biofilm measure 15x higher in stream with spawners than in control. Total macroinvertebrate densities 8-25 times higher	pink salmon
The biofilm (epilithic layer), all macroinvertebrates except shredders, and coho showed significant enrichment on MDN (N and C). Riparian enrichment of N. 34% of C in coho was of marine origin	Coho salmon
Mass spawning appears to lead to streambed alterations that influence embryo survival. Conclusion is that declines in mass-spawning populations may be difficult to reverse due the positive impact mass-spawning has on survival and productivity.	Chum salmon

Densities increased, condition factors increased. Fish were consuming carcasses and eggs.	Coho salmon
Reach an asymptote on ability to absorb MDN from spawning coho	Coho salmon
Appear to directly consume carcasses an incorporate lipids	Coho salmon
Density and size class structure positively influenced by proximity to spawning salmon	anadromous salmon
Spawning pinks salmon numbers were directly related to increase in R/S for the cohort of coho rearing in the stream when the pinks spawned	pink salmon
Had appreciable salmon eggs and fry dietary component	sockeye salmon
In vicinity of fish and carcasses, probably consumed some	Chum salmon
Spawners are primary source of N in stream	pink salmon
Current escapements, in the Pacific Northwest, deliver 6-7% of the MDN that was delivered 100-150 ybp	All species of anadromous salmon
Carcasses did not move far, with distance related to the amount of large organic debris in the stream	Coho salmon
Carcasses moved less than 600m, even at high flows. Generally retains close to point of deposition	Coho salmon
Provided with large amounts of N, as ammonia, from carcasses	Chum salmon
Enhanced by spawning salmon in fjord-like estuaries	Chum salmon
Ecosystems intimately linked to MDN	anadromous salmon
Diet shifted seasonally in some wolves to take advantage of spawning salmon	spawning salmon
Salmon critical food source	Chinook salmon, primarily
MDN stored overwinter for release in spring into riparian vegetation.	sockeye salmon
Plants, whether herbaceous or forested areas were similar, the hyporheic removal of dissolved nitrogen was noted	
Spawning salmon remove entrained fines. On average, mass spawning salmon moved over half of the annual sediment movement	probably early Stuart sockeye
Some pods in the northern resident grouping were strong associated with specific salmon runs. Depending on the pod, this could be pink, sockeye, or chum. Individual whales (some) were strongly associated with sockeye and Chinook runs	Chinook, pink, chum, and sockeye salmon
Increased abundance, size, and fecundity	Nutrient application

Addition of sewage-delivered nutrients, followed by reductions in sewage delivery, were directly correlated to striped bass population size	sewage effluent
Increased picoplankton abundance, increased phytoplankton biomass, increased primary productivity, and increased zooplankton biomass	Nutrient application
Primary productivity, chlorophyll-a, macrozooplankton, , Daphnia biomass all increased.	Nutrient application
All increase with no significant changes in water quality	Nutrient application
Riparian zone lizards appeared to preferentially feed on aquatic insects. This resulted in higher lizard growth rates and made terrestrial arthropods available to other consumers.	
Salmon carcasses composed a large portion of the diet in years of low rodent abundance	pink, chum, and coho salmon
target feeding on spawning salmon	pink, chum, and coho salmon
Large amounts of MDN delivered into upper watersheds/headwaters. Compounded by smolt emigration which may remove more mass than adults import.	Sea lamprey
MDN detected in wood samples	
The possibility of introducing bivalves to consume excess phytoplankton was examined as way to meet water quality targets	
Evidence is accumulating that overharvest of oysters in VA has led to declines in water quality and shifts in dominance of species in the Chesapeake Bay	
Resident rainbow responded positively in terms of reproductive output, growth, and yield to fertilizer application in lakes	nutrient application
Increased growth and abundance	Nutrient application, low level
Annual growth increment directly related to salmon carcass abundance	Stream spawning anadromous salmon
Direct relationship between escapement numbers and n enrichment	Salmon carcasses
Direct relationship between escapement numbers and n enrichment	Salmon carcasses
Absorbed MDN in such a way as to be useful for reconstruction of historic salmon escapements	pink and chum salmon
Trees growing near salmon spawning streams had significantly increased growth rates	pink and chum salmon

Increased size	Nutrient application
Increased growth and abundance	Nutrient application
Density increased, overwinter survival increased	Nutrient application
Increased growth and survival	Nutrient application
Primary production, periphyton biomass, heterotrophic activity, and nutrient concentrations greater in areas with salmon carcasses in winter	kokanee
Smolt yield increased, adult returns increased, smolt age decreased	Nutrient application
Addition of nutrients and instream habitat structure led to increases in juvenile numbers, juvenile size, smolt yield, and smolts per spawner. Steelhead population was below replacement recruitment prior to study; above it post study. Best results when habitat restoration and nutrient addition were combined, smallest benefit with habitat work only.	Nutrient application
Populations declined due to nutritional stress brought on by harvest of higher quality fish	gadids, herring, rockfish
Per capita food requirements varied with low-energy-density (gadids) vs. high-energy-density foods. Sea Lions ate fewer of the high energy fish in order to meet dietary/nutritional needs. High consumption of low-energy prey was associated with populations in the highest rates of decline	
Increased levels provided by red alder; low dissolved nutrient levels in old growth conifer forests.	leaf and litterfall
All aspects of productivity significantly increased	pink salmon
General summary of benefits to aquatic and terrestrial ecosystems	Salmon carcasses
General summary of benefits to aquatic and terrestrial ecosystems	spawning salmon
General summary of benefits to aquatic and terrestrial ecosystems	Salmon carcasses
General summary of benefits to aquatic and terrestrial ecosystems	Salmon carcasses
Salmon delivered MDN was utilized by terrestrial invertebrates through litter, soil, and vegetation N	Salmon carcasses
Absorbs MDN, often from piscivorous consumers, and transfers the MDN to consumers herbivores	spawning salmon
Developed escapement goals for a variety of WA rivers based on 0.15 for coho, 0.78 for massed spawners (chum, pink, and sockeye) and 0.39 for Chinook	Salmon carcasses
Increase MSY estimate for Karluk lake sockeye from approx 640K to .8-1 million	sockeye salmon

Direct consumption of lice fish, carcasses, and eggs	Chum salmon
Directly consumed carcasses	Coho salmon
basal area growth enhanced at sites receiving MDN inputs	spawning salmon
Consumed dead fish	alewife
Directly related to sockeye salmon escapement levels	sockeye salmon

CARCASS BIOMASS (kg/m²)	REFERENCE
	Fisher Wold and Hershey 1999
	Quamme and Slaney 2003
	Jardine et al. 2009
	Chaloner et al. 2002
	Nakajima and Ito 2003
	Jonsson and Jonsson 2003
	Elliott et al.1997
	Hunt et al. 1992
Eagles require 486g/bird/day. 13% of estimated escapement actually available to eagles	Hunt et al. 1992
	Restani et al. 2000 Leidholt-Bruner et al. 1992
	Pollock et al. 2004
75,000 spawners vs. 0	Wipfli et al. 1998
	Bilby et al. 1996
	Montgomery et al. 1996

	Bilby et al. 1998
0.15	Bilby et al. 2001
	Heintz et al. 2004
	Lang 2003
	Michael 1995
	Kline et al.1993
4.4-16.2-based on summer low flow	Jauquet et al. 2003
30K fish in 1.2 km	Kline et al. 1990
	Gresh et al. 2000
	Cederholm and Peterson 1985
	Cederholm et al. 1989
4.4-16.2-based on summer low flow	Jauquet et al. 2003
	Thompson 2001
	Naiman et al. 2009
	Darimont and richen 2002
	Jacoby et al. 1999
	O'Keefe and Edwards 2003
	Sabater et al.2003
	Hassan et al.2008
	Nichol and Shackleton 1996
	Pieters et al. 2003

Tsai et al. 1991

Stockner and MacIsaac 1996

Griswold et al. 2003

Pieters et al. 2003

Sabo and Power 2002

Ben-David et al. 1997

Ben-David et al. 1997

Nislow and Kynard 2009
Reimchen et al. 2003

Gottleib and Schweighofer 1996

Ulanowicz and Tuttle 1992

Johnston et al. 1999

Wilson et al. 2003

Drake et al. 2009

Reimchen et al. 2003

Reimchen et al. 2003

Drake et al. 2002

Helfield and Naiman 2001

	Barrowclough and Robinson 1972
	Budy et al. 1998
	Griswold et al. 2003
	Stockner and MacIsaac 1996
	Richey et al. 1975
0.6	Slaney et al. 2003
0.6	Ward et al. 2003
	Trites and Donnelly 2003
	Winship and Trites 2003
	Volk et al. 2003
	Wipfli et al. 1999
	Cederholm et al. 1999
	Cederholm et al. 1999
	Naiman et al. 2009
	Stockner 2003
	Hocking and richen 2002
	Ben-David et al. 1998
	Cederholm et al. 2001
	Schmidt et al. 1998

4.4-16.2- based on summer low flow	Jauquet et al. 2003
	Cederholm et al. 1989
	Helfield and Naiman 2002
individual deer eat 6.5 alewives per visit to beach	Case and McCullough 1987
	Gregory-Eaves et al. 2009